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NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

MARSHALL SPACE FLIGHT CENTER
THE UNIVERSITY OF ALABAMA

VERIFICATION OF COMPONENT MODE TECHNIQUES
FOR FLEXIBLE MULTIBODY SYSTEMS

Prepared By:

Gloria J. Wiens

Academic Rank:

Assistant Professor

University and
Department:

Auburn University
Mechanical Engineering

NASA/MSFC:

Laboratory:
Division:
Branch:

Structures and Dynamics
Control Systems Division
Pointing Control Systems

MSFC Colleague:

Dr. Henry B. Waites

Contract No:

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The University of Alabama

INTRODUCTION

Since the 1960's, a significant amount of theoretical work has been undertaken in the area of modeling and simulation of multibody systems. However, for systems having flexible components, there still seems to be no well defined method for selecting component modes for systems, in which due to large displacements, the boundary conditions of the original assumed modes varies. Furthermore, there has been very limited experimental verification of the existing modeling and simulation techniques. Hence, over the past fifteen months, research has been initiated with NASA/MSFC and Auburn University in the flexible multibody modeling and verification area [1-3]. The emphasis of the work is focused on the lack of experimental verification of current modeling and simulation techniques. In particular, analytical and experimental data is to be used in addressing the question of which boundary conditions and corresponding component modes should one use in describing the dynamics of flexible multibody systems. Other issues of interest are the gravity loading effects on geometric stiffening and the effects of configuration changes on assumed inertia values used in mode selection.

PROJECT DESCRIPTION

The proposed summer research activities were a continuation of last summer's project with NASA/MSFC. One of the selected tasks was to conduct further investigations in the modeling aspects of flexible multibodies undergoing large angular displacements. Models were to be generated and analyzed through application of computer simulation packages employing the 'component mode synthesis' techniques. The primary task set forth was the implementation of Phase I of the Multibody Modeling, Verification and Control Laboratory (MMVC) plan [1]. This was to include running experimental tests on flexible multibody test articles. From these tests, data was to be collected for later correlation and verification of the theoretical results predicted by the modeling and simulation process. The theoretical and numerical modeling techniques are being used in deriving a functional relationship and/or trends for as many of the issues stated above as possible.

MODELING ASPECTS

In addressing the modeling task, the work concentrated on the design of the first test article for Phase I of the MMVC experiments. This involved extensive NASTRAN analyses. In addition, ADAMS and TREETOPS numerical models were used to determine some preliminary estimates. Various materials,

configurations and dimensions were considered in the design process. After exhaustive study, a test article exhibiting low frequency characteristics, high modal density, a degree of dynamic coupling, and small static deflections due to gravitational loading was designed (see Figures 1-2 and Table 1). The resulting test article, currently under fabrication by NASA/MSFC, has the following material and dimension specifications.

Material of all members: Aluminum⁶⁰⁶¹
Young's Modulus, $E = 68.95 \times 10^9 \text{ N/m}^2$
Density = $2,768 \text{ kg/m}^3$

Dimensions:

Link 1: Length = 2.440m
Box Beam: Width, $b = 0.0762 \text{ m}$
Height, $h = 0.0254 \text{ m}$
Wall Thickness, $t = 0.0032 \text{ m}$
Link 2: Lengths (Two Branches) $L_a = 1.500 \text{ m}$, $L_b = 1.450 \text{ m}$
Solid Beam: Width, $b = 0.0335 \text{ m}$
Height, $h = 0.0090 \text{ m}$
Links 3, 4, 5, 6:
Lengths: $L_3 = 0.8200 \text{ m}$, $L_4 = 0.8000 \text{ m}$
 $L_5 = 0.7800 \text{ m}$, $L_6 = 0.7600 \text{ m}$
Solid Beam: Width, $b = 0.0050 \text{ m}$
Height, $h = 0.0020 \text{ m}$

With the addition of motor, joints and sensors, the first seven frequencies dropped approximately 1 Hz in value. In addition, there was approximately a 52 per cent reduction in modal density range of these frequencies. The cost for the fabrication of two test articles is under \$5,000.

The first generation of the test article's joints were designed to be light-weight and rigid. They were also designed using a pipe clamp approach to allow ease in changing body configurations. Since the initial testing will be for different static configurations of the test article, the joints will be fixed in each given configuration using a frictionless locking approach. Future improvements will be needed for the next phase of dynamic testing.

PHASE I IMPLEMENTATION

The implementation of Phase I of the MMVC Laboratory plan was not completed. However, important progress was made. Preliminary details and arrangements have been outlined for implementation once the test article is received (late September). The sensor and instrumentation specifications have been given. The base support which is to cantilevered off a platform in the west high bay area of building 4619 has been located and awaits mounting. In addition, the Base Excitation Table is in the process of being designed and fabricated between now and early November 1990. The joints will be fabricated once the test article has been received.

The above items will be carried out by NASA employees. According to their schedules, our first experimental testing is expected to be conducted between November and December.

REFERENCES

1. Wiens, G. J., "Multibody Modeling and Verification", Final Report, NASA/ASEE 1989 Summer Faculty Fellowship Program, Contract No. NGT-10-008-021, Marshall Space Flight Center, Huntsville, AL.
2. Tsai, H.-D., "Normal Modes and Static Analysis of MMV Design 1: Part I", edited by G. J. Wiens, NASA/MSFC Report, May 29, 1990.
3. Wiens, G. J., "Flexible Multibody Modeling and Mode Selection Dependencies", Six Months Technical Progress Report, Contract No. NASA/NAG8-123, August 27, 1990.

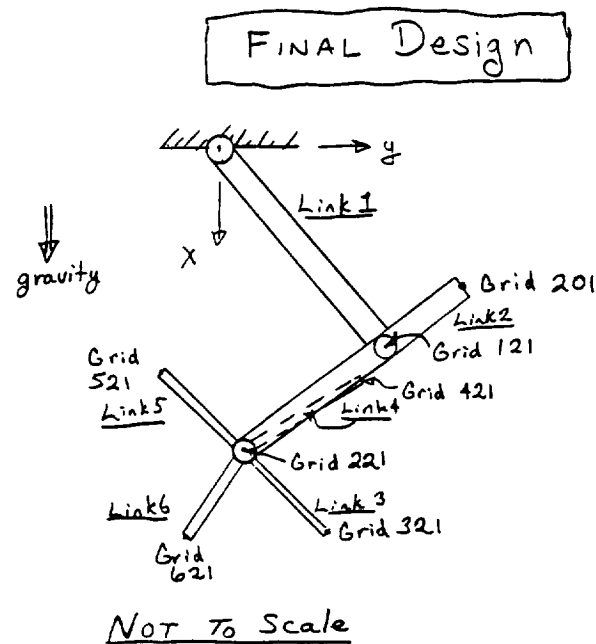


Figure 1.

FINAL DESIGN TABLE 1.

NORMAL MODE ANALYSIS FOR MMV DESIGN 12-NATURAL FREQUENCY

TEST ARTICLE 1: $\theta_1=0$ AND $\theta_2=0$

LINK1: A1 (HOLLOW-R, AL)

LINK2: A2 (SOLID-R, AL)

LINK3: A3 (SOLID-R, AL)

LINK4: A3 (SOLID-R, AL)

LINK5: A3 (SOLID-R, AL)

LINK6: A3 (SOLID-R, AL)

MODE NO.	SYSTEM MODE	COMPONENT MODE: LINK1	LINK2	LINK3
1	1.379	1.672	2.578	2.397
2	2.250	21.801	3.452	15.021
3	2.416	69.198	17.251	42.060
4	2.539	143.586	21.637	82.425
5	2.591	223.398	50.042	136.269
6	3.100	245.037	60.598	203.604
7	3.458	373.588	100.456	284.471
8	14.202	529.314	118.830	378.940
9	15.160	(Hz)	(Hz)	(Hz)
10	15.896			
11	15.972	LINK4	LINK5	LINK6
12	17.372	2.518	2.649	2.790
13	20.658	15.782	16.601	17.486
14	23.057	44.190	46.485	48.963
15	40.295	86.598	91.096	95.953
16	42.420	143.168	150.604	158.635
	(Hz)	213.912	225.022	237.021
		298.873	314.396	331.162
		398.124	418.802	441.135
		(Hz)	(Hz)	(Hz)

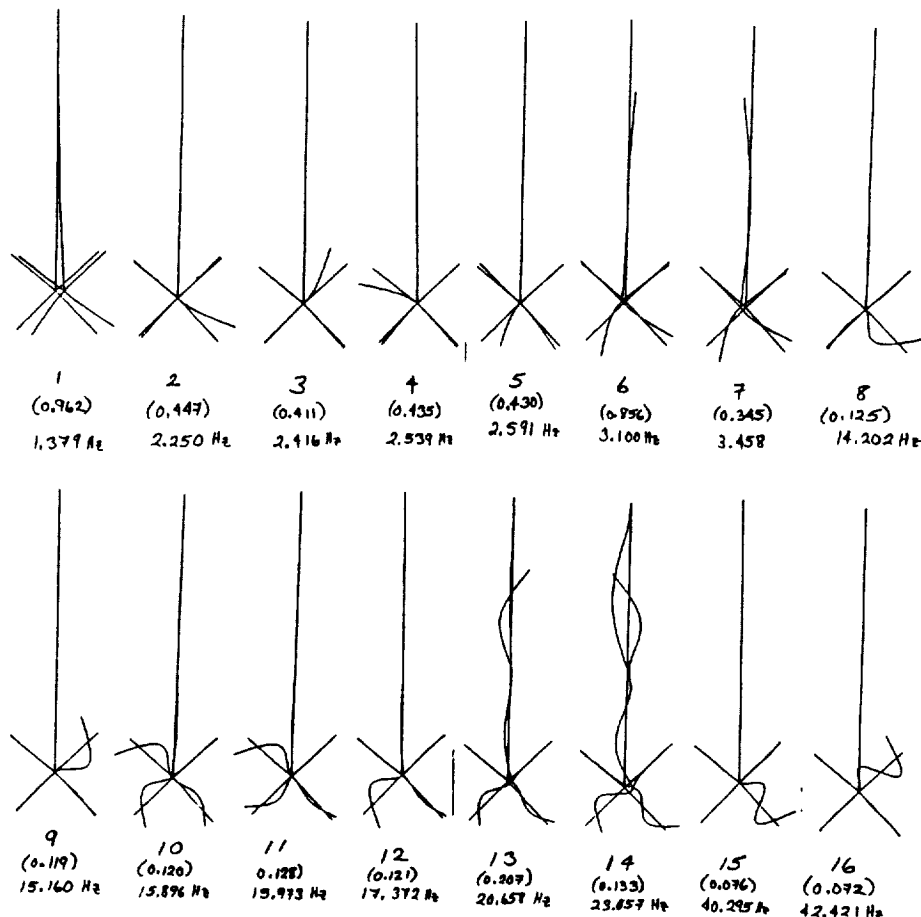


Figure 2. Mode Shapes

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